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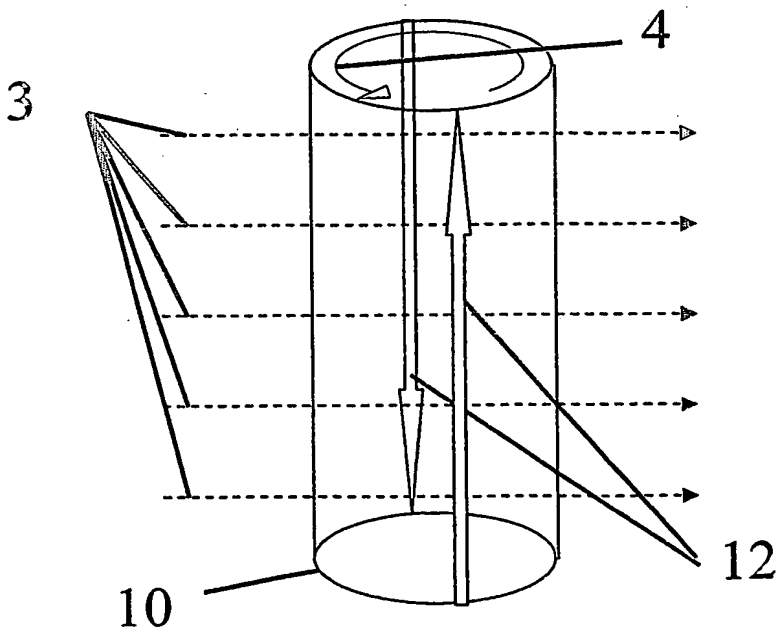
[Continued on next page]

(54) Title: AN APPARATUS AND A METHOD FOR INDUCTION HEATING OF PIECES OF ELECTRICALLY CONDUCTING AND NON-MAGNETIC MATERIAL



(57) Abstract: An apparatus and a method for induction heating of pieces or blanks (10) of electrically conducting and non-magnetic material, wherein a device creates a static magnetic field (3) and a second device is arranged to cause a relative movement (4) between the piece or blank (10) and the static magnetic field (3), so that current is induced (12) in the piece or blank (10) which thereby is being heated up.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

AN APPARATUS AND A METHOD FOR INDUCTION HEATING OF PIECES OF ELECTRICALLY CONDUCTING AND NON-MAGNETIC MATERIAL.

This invention relates to an apparatus and a method for induction heating of pieces or blanks of electrically conducting and non-magnetic material.

Induction heating is used in force pressing in order to soften up metal bolts or billets before they are being pressed into profiles. For non-magnetic materials which are good electrical conductors, such as aluminium, copper or brass, conventional induction heating has an efficiency of only 55-60%. In such conventional heating processes a bolt or billet is axially placed within a coil. Alternating current is applied to the coil, so that an axial alternating magnetic field is produced. Consequently counter-current is induced in the bolt or billet to counteract the magnetic field. In this case the induced current heats the press bolt or billet. The problem here is that the current in the coil causes losses that are of the same size as in the bolt or billet, which causes the efficiency to become low.

Induction heating devices can also be equipped with superconducting coils for alternating current, cf. Norwegian Patent No. 308.980. Superconductors, however, produce losses when they are exposed to an alternating magnetic field. A problem that can occur here is that the heat from the AC losses in the superconductors must be cooled away (at approximately 50-90 Kelvin), and the cooling system, that is needed, is expensive.

Recently, there have appeared possibilities for formation of a static or DC magnetic field without energy losses. Superconductors can, under DC conditions, conduct electric current practically without losses, and strong permanent magnets have become available at a reasonable price. In the solution proposed here the superconductors

are substantially exposed only to a static or DC magnetic field, and therefore a substantially smaller cooling system is required, which is also cheaper than the one used in the induction heating apparatus employed in Norwegian Patent No. 308.980.

In a preferred embodiment the present invention teaches inducing electric current to heat up a material by allowing the material to be moved in a magnetic field. It is known that in an electrically conducting material, being moved orthogonal to a static magnetic field, an electric field is established being perpendicular to the direction of movement and the magnetic field. The electric field induces currents which then cause resistive losses that are heating up the material.

In the same way, currents are induced in an electrically conducting material if it is moved in the direction of the static field when the intensity of the field is also varied in the same direction.

In a typical embodiment of the invention a workpiece, blank or bolt, for example a cylindrical press bolt or billet of good electrically conduction and non-magnetic material, is rotated in a static magnetic field orientated perpendicular to the axis of the bolt or billet. The static magnetic field can for example be created by applying a DC current through a superconductor or by using permanent magnets. It is also possible to combine permanent magnets and superconductors in order to generate a static magnetic field. The energy, that is used for the heating up, is provided by means of a motor or the like which drives the device creating a relative movement. For example a rotating or linear electrical motor can be used. In the proposed rotating induction heating apparatus the degree of efficiency of the heating process is mainly determined by the efficiency of the motor providing the rotation. An electrical motor has a typical efficiency of

90% or more, which is substantially better than the 55-60% considered for conventional induction heaters for aluminium, copper or brass bolts or billets.

When superconductors are used in the induction heating apparatus according to the invention, the effect in the piece, blank, bolt or billet can be controlled by varying the level of the magnetic field. In the same way it can be controlled which area of the piece, blank, bolt or billet to be most heated by connecting coils that are wound on different places along the axis of the piece, blank, bolt or billet.

The degree of efficiency is affected to a very little extent when the dimensions of the piece, blank, bolt or billet are changed.

It is further possible to combine the static magnetic field with an alternating magnetic field in order to create a common magnetic field arranged to heat up the electrically conducting and non-magnetic piece or blank.

Instead of moving linear or rotating the piece or blank, the device, creating the static magnetic field, can be moved linear or rotated.

The novel and characteristic features of the invention are stated more closely in the claims.

The most important advantage of the apparatus and the method according to the present invention is that the degree of efficiency can be considerably increased. It goes up from approximately 55-60% to 90% or more in relation to conventional methods. This is obviously quite considerable and shows that it is here a matter of a new solution of high practical value to the industry.

In what follows the invention will be explained more closely with reference to the drawings which schematically and simplified show different embodiments that are practically possible.

Fig. 1 shows schematically an embodiment of an apparatus according to the invention;

Fig. 2 shows an embodiment according to the invention comprising a coil that creates a static magnetic field, where the piece or blank is rotated;

Fig. 3a shows an alternative embodiment according to the invention comprising permanent magnets surrounding the piece or blank, where the piece or blank is rotated;

Fig. 3b shows a horizontal cross section of fig. 3a, where the magnetic lines are indicated;

Fig. 3c shows a horizontal cross section of a third embodiment according to the invention comprising permanent magnets surrounding the piece or blank, where the permanent magnet device creating the static magnetic field is rotated;

Fig. 3d shows a horizontal cross section of a fourth embodiment according to the invention comprising permanent magnets which do not surround the piece or blank;

Fig. 4a shows a fifth embodiment according to the invention comprising a coil having annular sections surrounding the piece or blank and being connected in anti-parallel, where piece or blank is moved linear and where the currents induced in the piece or blank are indicated;

Fig. 4b shows a vertical cross section of fig. 3a, where the magnetic lines are shown.

Fig. 1 shows schematically an apparatus where a piece or blank 10, for example a cylindrical press bolt or billet of electrically well conductive and non-magnetic material is rotated 4 in a static magnetic field 3 orthogonally orientated in relation to the axis of the piece or blank. In the rotating piece or blank 10 there is set up an electrical field being orthogonal in relation to

the direction of movement 4 and the magnetic field 3. The electrical field induces currents 12 in the piece or blank 10 which then give resistive losses heating up the piece or blank 10.

Fig. 2 shows an apparatus for induction heating of the piece or blank 10 of electrically conducting and non-magnetic material, comprising a device for creating of a static magnetic field and a device 2 arranged to cause a relative movement 4 between the piece or blank 10 and the static magnetic field. The device for creating of the static magnetic field comprises a coil 52. The magnetic field is created by applying a direct current 11 to the coil 52 and in combination with the rotational movement 4 of the piece or blank 10 currents 12 are induced in piece or blank 10 giving resistive losses thereby heating up the piece or blank 10. The coil 52 can have windings which can be of superconducting material. The device for movement/rotation comprises two shafts or spindles 2 gripping in towards the end sections of the piece or blank 10.

On fig. 3a an alternative embodiment according to the invention is illustrated, where the device creating the magnetic field comprises permanent magnets 51 and which in this case surrounds the piece or blank 10. The annular permanent magnet device 51 comprises several poles, for example four, so that the magnetic field 31, that is created, will be directed into and out of the piece or blank 10 several times along its periphery, since the spindle device 2 as shown on fig. 2 is arranged to cause a relative rotational movement 4 between the piece or blank 10 and the static magnetic field 31. The magnetic lines of the static magnetic field 31 are shown on fig. 3b and 3c. Fig. 3c illustrates however a cross section of a third embodiment according to the invention, where the device for creating of the magnetic field is being rotated 41, and the piece or blank 10 is stationary.

Fig. 3d shows a fourth embodiment according to the present invention, where the device for creating of the magnetic field 31A comprises a more open arrangement of permanent magnets 51A which do not surround the piece or blank 10. In this case it is preferred to rotate 4 the piece or blank 10.

A fifth embodiment according to the invention shown on fig. 4a and 4b, comprises a coil 53 having annular sections surrounding the piece or blank 10 and being connected in anti-parallel, so that the static magnetic field 32, which is created, varies in axial direction, since the device 2 for relative movement is arranged to cause a relative linear movement 42 in the same axial direction between the piece or blank 10 and the static magnetic field 32. The piece or blank 10 is being heated up by the induced currents 12A. The coil 53 can advantageously have windings of superconducting material. Instead of a coil 53 it is also possible to use permanent magnets in a similar annular and sectionized device for creation of the static magnetic field 32.

According to the invention the device for creation of relative movement can rotate or move linearly along the axis 6 of the piece or blank 10, i.e. either the piece or blank 10 in relation to the static magnetic field or the device for creation of the static magnetic field in relation to the piece or blank 10 which is stationary. It is possible to relatively move both the device for creation of the field and the piece or blank in relation to each other, but this is complicated and therefore is not preferred.

In the device creating the magnetic field it is possible to use a combination of both permanent magnets and windings/coils.

Additionally the described apparatus for induction heating can comprise a device for creation of an alternating magnetic field, so that the static magnetic field, mentioned before, is combined with the alternating magnetic field thereby having a total or common effect on the piece or blank 10.

Claims

1. Apparatus for induction heating of pieces or blanks (10) of electrically conducting and non-magnetic material, characterized in that it comprises a device for creating a static magnetic field (3) and a device (2) for causing a relative movement (4) between the piece or blank (10) and the static magnetic field (3), so that current (12) is induced in the piece or blank (10) which thereby is being heated up.

2. Apparatus according to claim 1, wherein the device for creation of the static magnetic field (3,32) comprises at least one coil (52,53) adapted to entirely or partially surround the piece or blank (10).

3. Apparatus according to claim 2, wherein the at least one coil (52,53) has windings comprising superconducting material.

4. Apparatus according to claim 2 or 3, wherein the at least one coil (52,53) has annular sections surrounding the piece or blank (10) and being connected in anti-parallel, so that the static magnetic field (32), which is created, varies in axial direction, the device (2) for relative movement being arranged to cause a relative linear movement (42) in the same axial direction between the piece or blank (10) and the static magnetic field (32).

5. Apparatus according to claim 1, wherein the device for creating of the static magnetic field (3,31) comprises at least one permanent magnet (51).

6. Apparatus according to claim 5, wherein the at least one permanent magnet (51) is included in an annular permanent magnet device arranged to surround the piece or blank (10).

7. Apparatus according to claim 6, wherein the annular permanent magnet device (51) comprises several poles, for example four, so that the magnetic field (31), that is created, is directed into and out of the piece or blank (10) several times along its periphery, the device (2) for relative movement being arranged to cause a relative rotational movement (4) between the piece or blank (10) and the static magnetic field (31).

8. Apparatus according to claim 6, wherein the annular permanent magnet device comprises a number of annular sections, so that the static magnetic field, that is created, varies in axial direction, the device (2) for relative movement being arranged to cause a relative linear (42) movement in the same axial direction between the piece or blank (10) and the static magnetic field.

9. Apparatus according to any one of claims 1-8, wherein the device (2) for relative movement is arranged to move the piece or blank (10) in relation to the static magnetic field (3,31,32).

10. Apparatus according to any one of claims 1-8, wherein the device for relative movement is arranged to move the device for creation of the static magnetic field (3,31,32) in relation to the piece or blank (10).

11. Apparatus according to any one of claims 1-10, wherein the device for creation of the static magnetic field (3,31,32) comprises at least one permanent magnet (51) and at least one coil (52,53) preferably comprising windings of superconducting material.

12. Apparatus according to any one of claims 1-11, further comprising a device for creation of an alternating magnetic field, so that the static magnetic field (3,31,32) is combined with the alternating magnetic field thereby having a common effect on the piece or blank (10).

13. Method for induction heating of pieces or blanks (10) of electrically conducting and non-magnetic material, characterized in that it comprises the following steps:

- creating a static magnetic field (3,31,32), and
- causing a relative movement (4,41,42) between the piece or blank (10) and the static magnetic field (3,31,32), so that current (12,12A) is induced in the piece or blank (10) which thereby is being heated up.

AMENDED CLAIMS

[received by the International Bureau on 13 May 2004 (13.05 04);
original claims 1-13 replaced by amended claims 1-11;
claims 12-13 canceled, (pages 03)]

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STATEMENT

1. Apparatus for induction heating of pieces or blanks (10) of electrically conducting and non-magnetic material, comprising a device for creating a static magnetic field (3) and a device (2) for causing a relative movement (4) between the piece or blank (10) and the static magnetic field (3), so that current (12) is induced in the piece or blank (10) which thereby is being heated up, wherein the device for creation of the static magnetic field (3) comprises at least one coil (52,53) comprising windings of superconducting material.

2. Apparatus according to claim 1, wherein the at least one coil (52,53) is adapted to entirely or partially surround the piece or blank (10).

3. Apparatus according to claim 1 or 2, wherein the at least one coil (52,53) has annular sections surrounding the piece or blank (10) and being connected in anti-parallel, so that the static magnetic field (32), which is created, varies in axial direction, the device (2) for relative movement being arranged to cause a relative linear movement (42) in the same axial direction between the piece or blank (10) and the static magnetic field (32).

4. Apparatus according to claim 1 or 2, wherein the device for creating of the static magnetic field (3,31) further comprises at least one permanent magnet (51).

5. Apparatus according to claim 4, wherein the at least one permanent magnet (51) is included in an annular permanent magnet device arranged to surround the piece or blank (10).

6. Apparatus according to claim 5, wherein the annular permanent magnet device (51) comprises several poles, for example four, so that the magnetic field (31), that is created, is directed into and out of the piece or blank (10) several times along its periphery, the device (2) for relative movement being arranged to cause a relative rotational movement (4) between the piece or blank (10) and the static magnetic field (31).

7. Apparatus according to claim 5, wherein the annular permanent magnet device comprises a number of annular sections, so that the static magnetic field, that is created, varies in axial direction, the device (2) for relative movement being arranged to cause a relative linear (42) movement in the same axial direction between the piece or blank (10) and the static magnetic field.

8. Apparatus according to any one of claims 1-7, wherein the device (2) for relative movement is arranged to move the piece or blank (10) in relation to the static magnetic field (3,31,32).

9. Apparatus according to any one of claims 1-7, wherein the device for relative movement is arranged to move the device for creation of the static magnetic field (3,31,32) in relation to the piece or blank (10).

10. Apparatus according to any one of claims 1-9, further comprising a device for creation of an alternating magnetic field, so that the static magnetic field (3,31,32) is combined with the alternating magnetic field thereby having a common effect on the piece or blank (10).

11. Method for induction heating of pieces or blanks (10) of electrically conducting and non-magnetic material, comprising the following steps:

- creating a static magnetic field (3,31,32), and
- causing a relative movement (4,41,42) between the piece or blank (10) and the static magnetic field (3,31,32), so that current (12,12A) is induced in the piece or blank (10) which thereby is being heated up, wherein the static magnetic field (3,31,32) is being produced by at least one coil (52,53) comprising windings of superconducting material.

STATEMENT UNDER ARTICLE 19 (1)

Reference is made to the International Search Report having the 23rd of March 2004 as a mailing date.

New amended claims are presented.

The new amended apparatus claim 1 is based on features taken from the original claims 1, 2 and 3.

The original claim 11 is cancelled.

The new amended method claim 11 is based on features taken from the original claims 13, 2 and 3, and the description.

There is not introduced any new matter to the amended claim set.

None of the cited publications discloses that the device for creation of the static magnetic field comprises at least one coil comprising windings of superconducting material. Moreover the piece or blank, that is to be heated, is of electrically conducting and non-magnetic material.

We respectfully request that the Examiner considers the above arguments when examining the amended claims and preparing the International Preliminary Report on Patentability (IPRP).

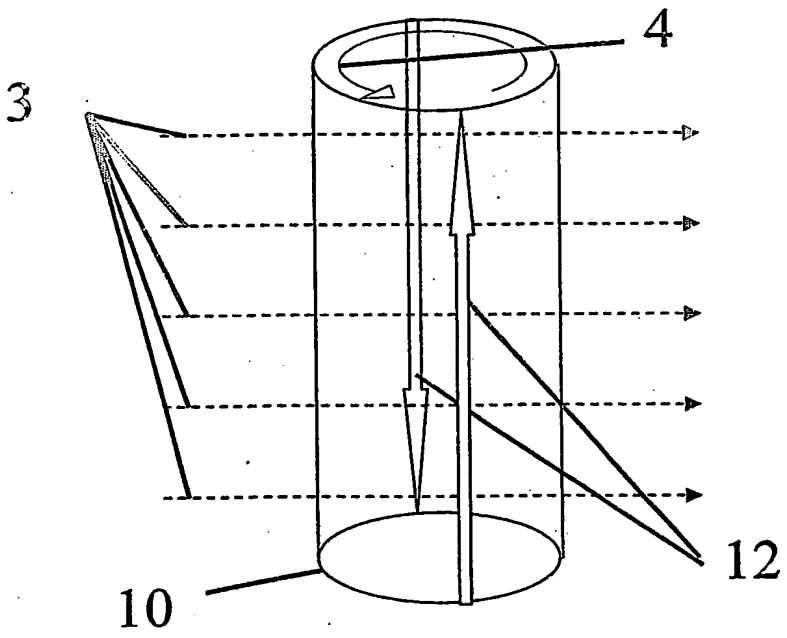


Fig. 1

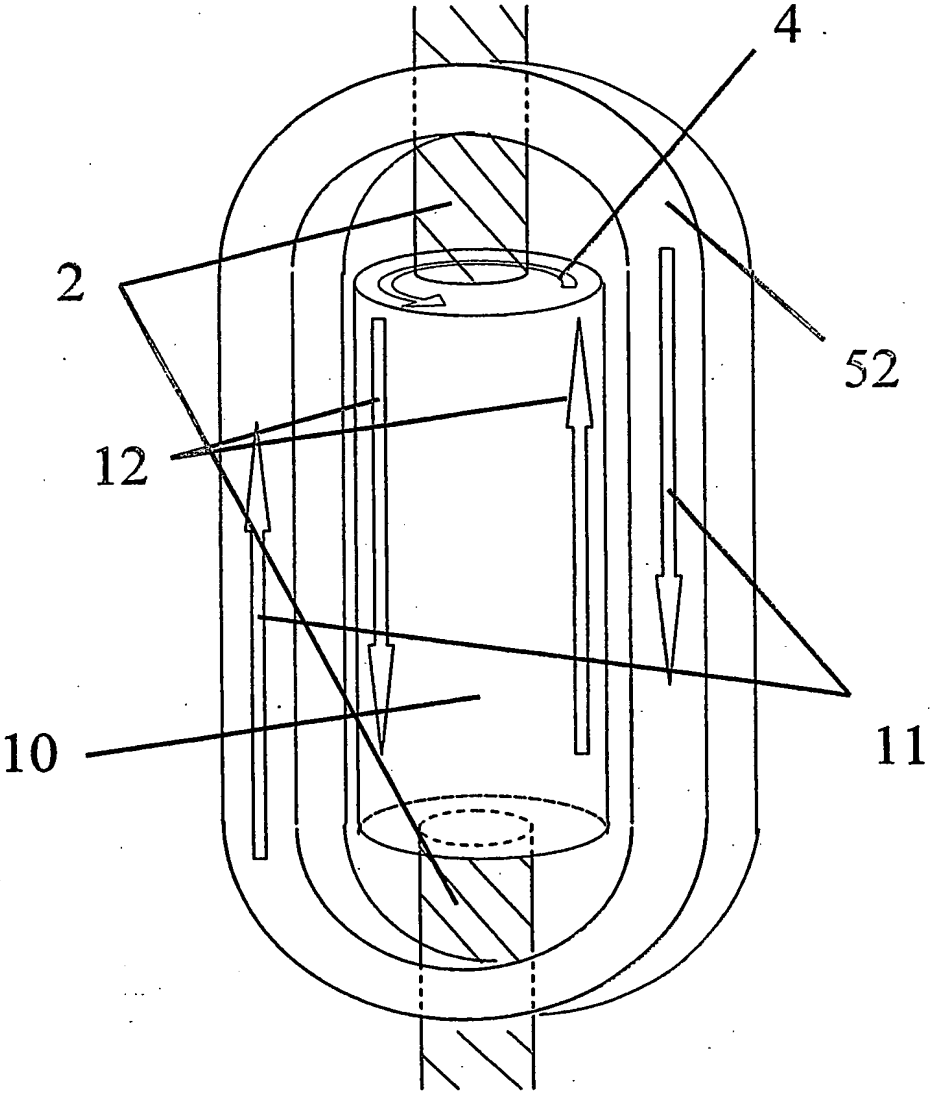


Fig. 2

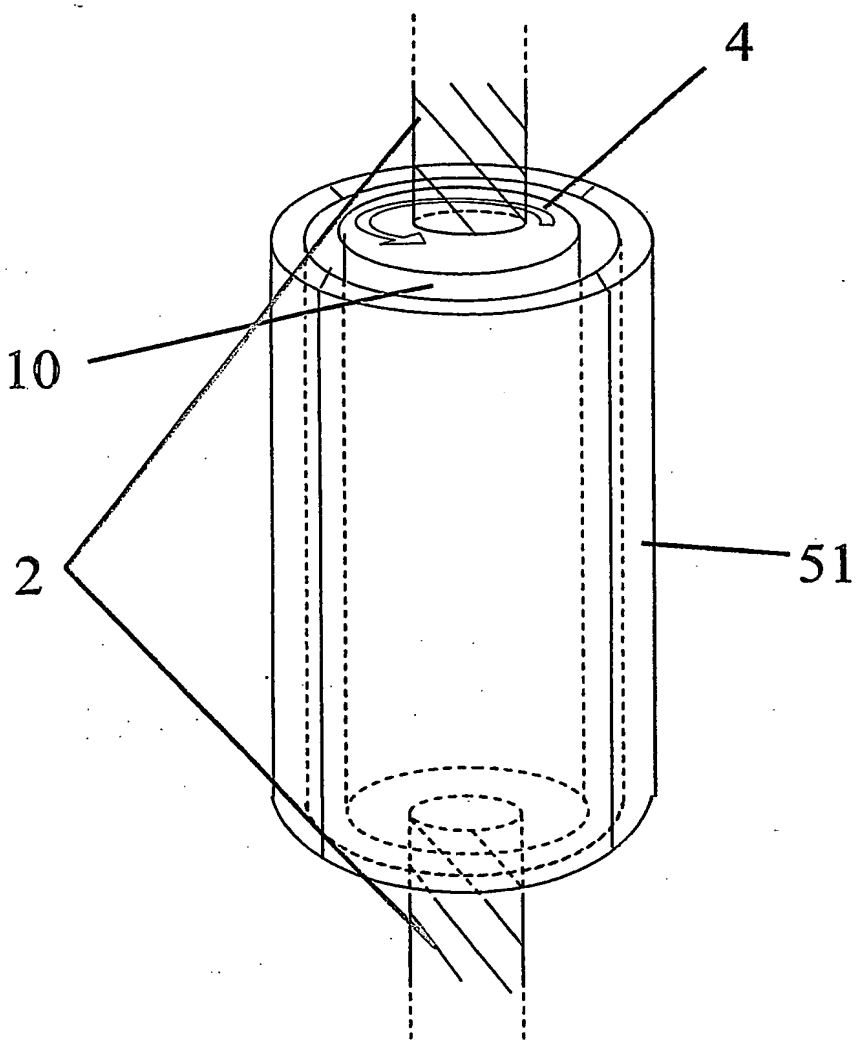


Fig. 3a

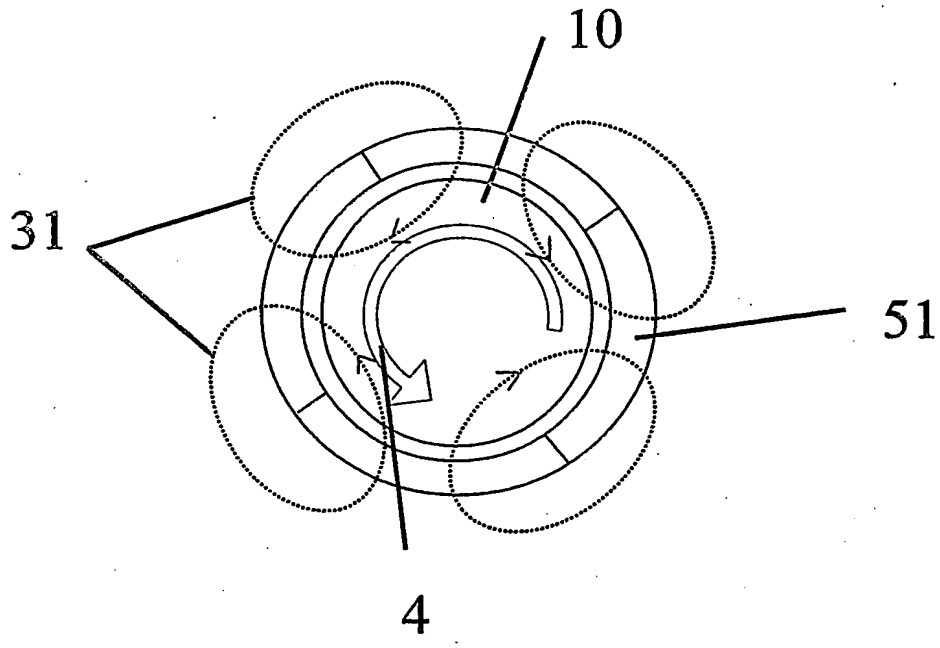


Fig. 3b

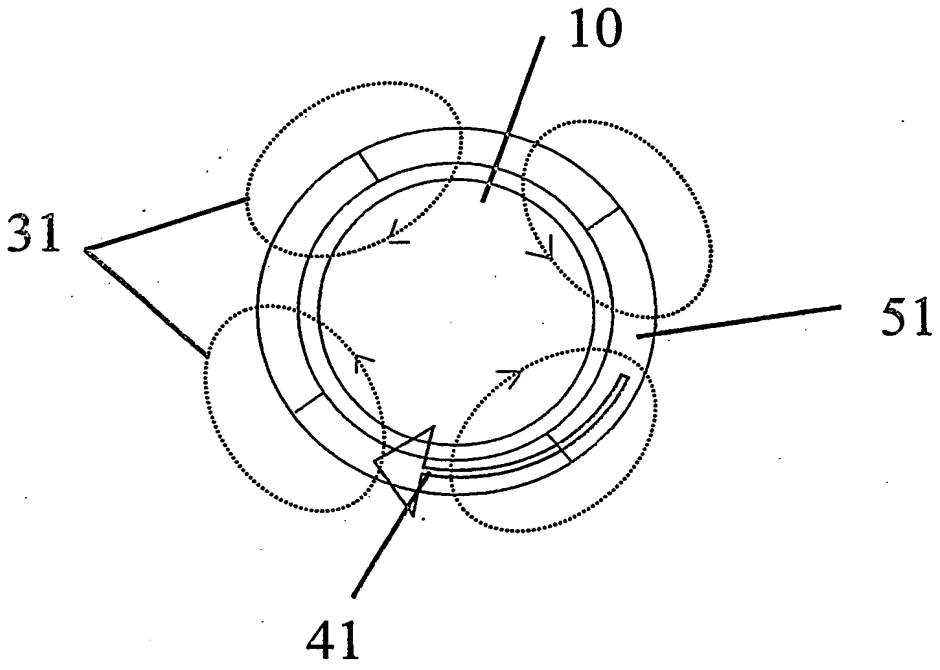


Fig. 3c

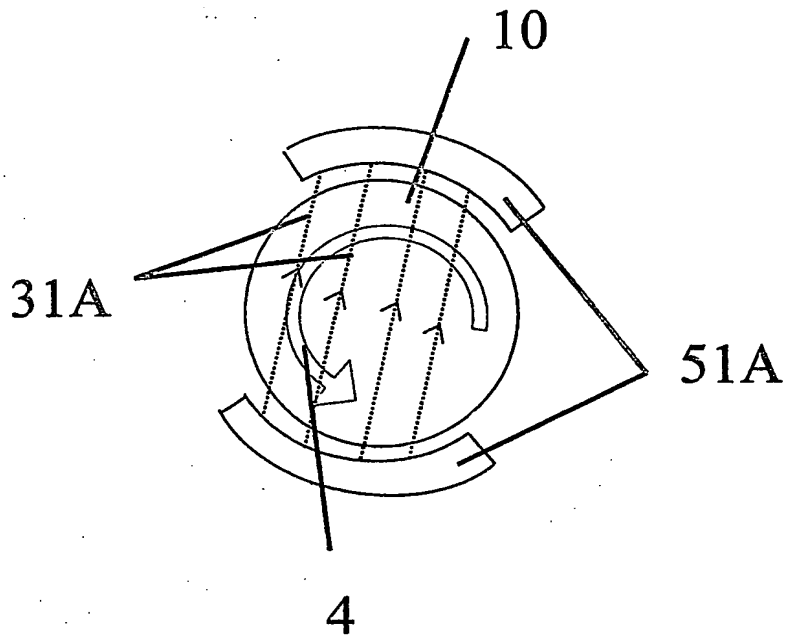


Fig. 3d

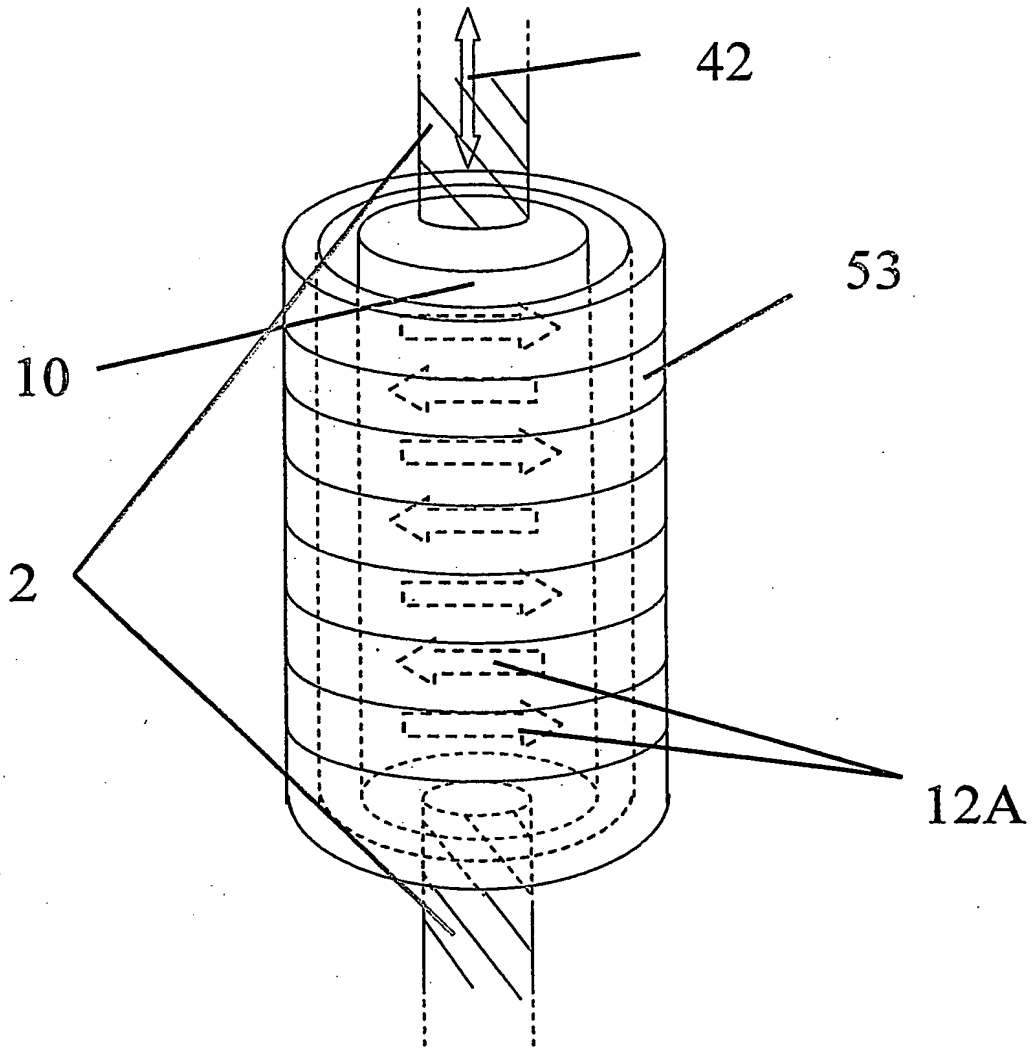
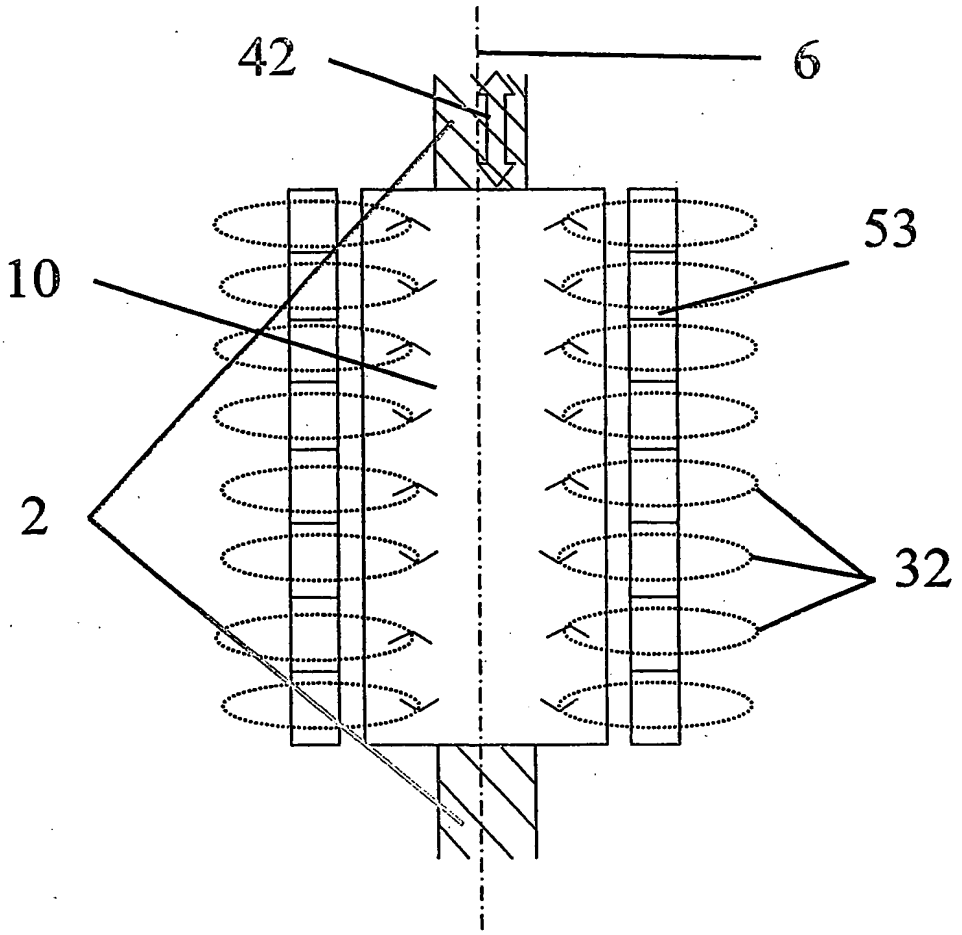


Fig. 4a

Fig. 4b



INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2003/000394

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H05B 6/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2912552 A (M.BAERMANN), 10 November 1959 (10.11.1959), column 5, line 9 - column 6, line 48, figures 1-5	1,2,5-7, 9-11,13
X	WO 02087285 A1 (ROSASTRO, PAOLO, ARNALDO), 31 October 2002 (31.10.2002), page 2, line 33 - page 9, line 14, see the figures	1,5-7,9,10, 13
X	US 4761527 A (GLENN R. MOHR), 2 August 1988 (02.08.1988), column 4, line 48 - column 8, line 14, figures 1-14	1,2,5,9-11, 13

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 March 2004	23 -03- 2004
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Westöö/MN Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

Information on patent family members

27/02/2004

International application No.
PCT/NO 2003/000394

US	2912552	A	10/11/1959	NONE			
WO	02087285	A1	31/10/2002	IT	MI20010835	A	21/10/2002
US	4761527	A	02/08/1988	NONE			